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ANNUAL REPORT #2

March 1, 1993 -- February 28, 1994

AFOSR Grant # F49620-92-J-0176-P00002

PI -- William R. Uttal

Studies of the Effect of Image Degradation and Recombination

I: Summary

The second year of this grant has been very productive. We completed the major study that was underway last year and have moved on to complete two other major programmatic studies. The ongoing study that is now complete was the one in which we explored the effects of noise, Fourier filtering, reduced acuity (by means of blocking) and combinations thereof in a discrimination task. Ten experiments were carried out in this series. A publication on this work has been submitted for publication and is now being reviewed. From there we went on to consider the combination of degradations by the visual system rather than by means of the computer. In this study degraded images were combined with dichoptic viewing. A manuscript describing this work has also been submitted and is under review. We then undertook to study the effect of combinations of degradations on a recognition task. That work has also been completed and is in the process of being analyzed. The first paper submitted from our laboratory on the psychophysical foundations of night vision devices has been accepted for publication.

II: Research Objectives

1. This project offers a program of research on the psychophysics of form. It specifically deals with the perception of degraded and incomplete images. We are interested in the effect of image degradation of the ability of an observer to detect, discriminate, and recognize objects and scenes when the quality of the image has been reduced by systematic, quantified image transformations.

2. We are also interested in the complementary and closely related problem of sensory fusion -- how can multiple aspects or dimensions of the degraded and incomplete images be visually processed so that their subjective appearance is of a higher quality than it would otherwise be, and thus the observer's performance be enhanced from what it would

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otherwise be. The basic question in this complementary case deals with the ability of the visual system to integrate or combine low quality images of, for example, differing resolution to produce a high quality perception. It is a search for the rules of visual spatial combination and for the relative efficacy of what are distinguishable aspects or attributes of stimuli.

3. The two questions are, therefore, two aspects of the same problem. One the one hand, what effect does degradation have on the percept? and, on the other, how can the effects of image degradation be overcome by utilizing the power of the visual system to integrate or combine degraded images?

4. We approach this problem from two different directions. First, we are carrying out a program of psychophysical studies that examines the effects of degradation and search out the nature of visual multidimensional combination. The long range goals of the psychophysical experiments are to provide information about the effects on performance of the human observer that go beyond rating or ranking of the subjective quality of an image. Second, we will develop computer models and measures of the effects of image degradation and of the visual combination process. The models so generated are intended to provide the foundation of a theoretical standard observer that can ultimately be used to measure and predict image "quality."

III Status of Research

The second year of our work has continued to be productive. First, we completed the series of experiments from the previous year studying how combinations of image degradations affect discrimination. This work may be summarized as follows:

This work explored the ways in which combinations of image degradations affect discrimination. Nine experiments are described that examine the discriminability of visual images that are degraded with three types of information reducing transformations -- random punctate visual interference, low-pass spatial frequency filtering, and local area averaging. The results of these experiments characterize a powerful visual ability to discriminate highly degraded stimuli unless severely challenged by relatively high levels of random visual interference. An important result is a demonstration of an apparent perceptual commutativity of the orders in which the other two degradations are imposed. That is, the order in which the degradations are applied does not affect the final discriminative

outcome. This result is in contrast to predictions from relevant mathematics and direct examination of the images produced by both orders of degradation. The commutativity is attributed to the particularly strong effect of the low-pass spatial frequency filtering degradation on the discrimination process. This study also demonstrates that combinations of degradations in a discrimination task always result in a reduction in performance, never an improvement as has been reported for recognition. This difference is attributed to the fact that form discrimination is mediated by local features and high frequency spatial components, whereas recognition is mediated by global features and low frequency spatial components.

Second, we completed a study of dichoptic combination of degraded images. This work may be summarized as follows:

Two experiments were carried out in which information from two different kinds of degraded (low-pass filtered and regionally averaged or blocked) visual stimuli were combined. In the first experiment, the degraded images are perceptually combined by being separately presented to each eye in a dichoptic viewing situation. Both stimuli are masked by identical random visual interference. When the two stimuli are dichoptically presented visually fused, performance in a discrimination task is enhanced over control situations in which only one of the two stimuli is presented. In the second experiment, the two degraded stimuli are physically superimposed prior to binocular presentation with a similar result. We conclude that a true advantageous information pooling is occurring when these two types of degraded stimuli are combined either physically or dichoptically. The implications of these findings for understanding the function of the visual system are discussed.

Third, we have completed data collection on a ten experiment study in which we explored the effects of these same combinations of attributes in a recognition task. The most important development that has emerged so far has been the confirmation of the Harmon and Julesz phenomenon (i. e., low pass filtering of a blocked image enhances perception) for recognition but the rejection of it for discrimination. The data is now being analyzed and prepared for publication.

Finally, we are currently at work studying face recognition as another model stimulus. In all of the previous work small aircraft silhouettes were used as targets. The face is a stimulus that offers somewhat greater complexity and opportunities for examining a more realistically challenging domain.

IV Publications

a. Published Articles:

1. Uttal, W. R. Toward a new behaviorism (1993). In Masin, S. (Ed.) Conceptual Foundations of Perceptual Theory. Amsterdam: North Holland.
2. Uttal, W. R. (1994). Pattern recognition. In Ramachandran, V. S. (Ed.) Encyclopedia of Human Behavior. Academic Press.
3. Uttal, W. R., Shepherd, T. Dayanand, S., Lovell, R. (1993). An integrated computational model of a perceptual-motor system. In Meyer, J., Roitblat, H. L., & Wilson, S. W., (Eds.) From Animals to Animats. Cambridge, MA: MIT Press.

c. In Press Articles:

1. Uttal, W. R. Introduction to Psychophysiology of Visual Masking (Bachmann, T. Author), Commack, New York: Nova Science Publishers. (In Press)
2. Uttal, W. R., Baruch, T., & Allen, L. Psychophysical foundations of amplified night vision in target detection tasks. (In press - Human Factors)
3. Dayanand, S., Uttal, W. R., Shepherd, T., Lunsakis, C. A particle system model for combining edge information from multiple segmentation modules. (In press - Computer Vision, Graphics, and Image Processing: Graphical Models and Image Processing).
4. Uttal, W. R., Dayanand, S., Shepherd, T., Lunsakis, C., Kalki, J., Ramamrutham, N. A computational theory of object perception: Progress and Potential Applications. (In Press Proceedings of USN Mine Counter Measures Symposium, Panama City, Florida. November 9-10, 1993.)
5. Uttal, W. R., The old gray vision science -- She ain't what she used to be. Review of Digital Images and

Human Vision by Watson, A. B. (Ed.) Cambridge, MA: The MIT Press.) (In press - IEEE Multimedia)

c. Submitted Articles Being Reviewed.

1. Uttal, W. R. Baruch, T. & Allen, L. The effect of combinations of image degradations in a discrimination task. (Submitted)
2. Uttal, W. R., Baruch, T. & Allen, L. Dichoptic and physical information combination: A comparison. (Submitted)
3. Uttal, W. R. The perception of faces: Task and attribute effects. (Submitted)
4. Uttal, W. R., Davis, N. S., and Welke, C. Stereoscopic perception with brief exposures. (Submitted)

e. Planned Articles

Effect of Image Degradations on Recognition

V Participating Staff

William R. Uttal, B. S, Ph.D.	PI
Todd Baruch, B. S.	Research Assistant
Linda Allen, B. S.	Graduate Student
Takeo Watanabe, Ph.D.	Assistant
Professor	

VI Coupling Activities

Presentations

1. Uttal, W. R. 17-22 January 1993. Toward a new behaviorism. Interdisciplinary Conference, Jackson Hole, Wyoming.
2. Uttal, W. R. 14-15 May 1993. Adding and subtracting image degradations. Society for Experimental Psychology, Seattle, Washington.
3. Uttal, W. R. 5-9th July 1993. Five invited lectures on computational modeling and psychophysics. University of Padua, Italy.
4. Uttal, W. R., Baruch, T., and Allen, L. 7 November 1993. Combining degraded images. The Psychonomics Society, Washington, D. C.
5. Uttal, W. R. et al. 9 November 1993. A computational model of a perceptual motor system. USN Symposium on Mine Countermeasures, Panama City Florida.

Editorial

Uttal was appointed consulting editor of the new APA journal
Journal of Experimental Psychology: Applied

VII New Developments

There were no new patents. Discoveries are of the kind described above. Application of our work is relevant to night vision devices and image quality.

VIII Supplementary Information

Progress was very good this year. Publication lags are keeping us "in press" and "submitted" longer than I would like but given our cold start two years ago, our productivity is high.

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